Portable Parallel Beam X-Ray Diffraction System For In-Line Process Control in the Steel Industry

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Project Description

- **Design, build and test a compact in-line X-ray diffraction system to perform identification and quantification of Zeta phase formation in a galvannealing line.**

Project Objectives/Goal

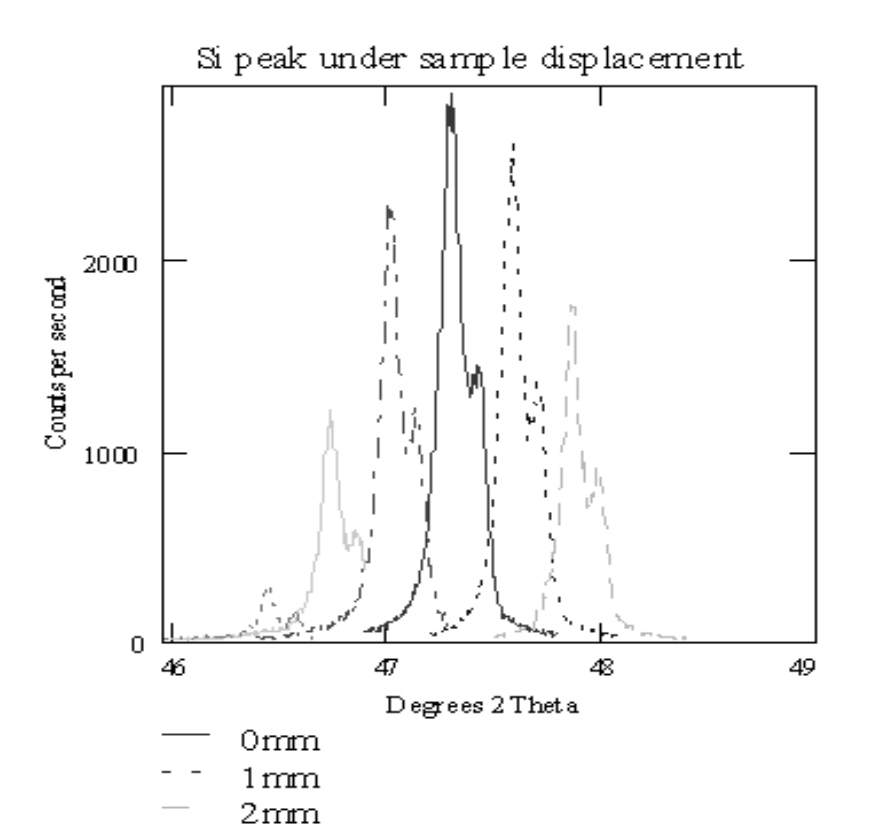
- **A robust sensor to monitor and control zeta phase in-line for the steel galvannealing process.**

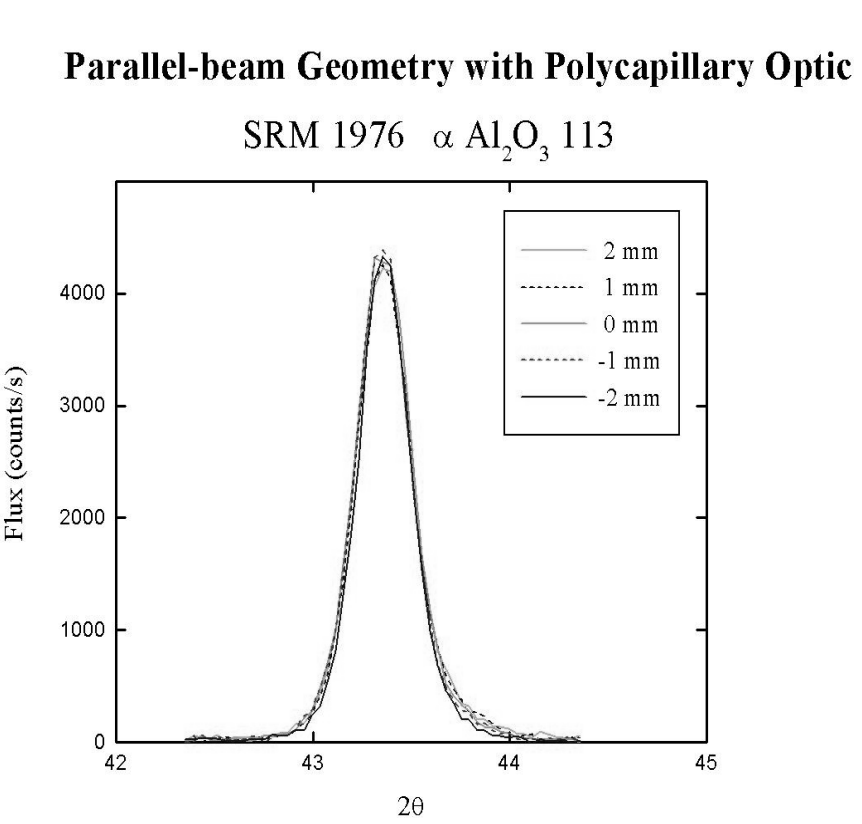
- **A capability which can be used for crystalline measurement in-line in a broad range of applications and industries.**

Innovation/Technical Risks

- **Innovation**
  - Parallel Beam Geometry via x-ray optics
  - Non-scanning technique
- **Technical risks**
  - Alignment of source, sample, optic, and detector
  - Reliability and reproducibility

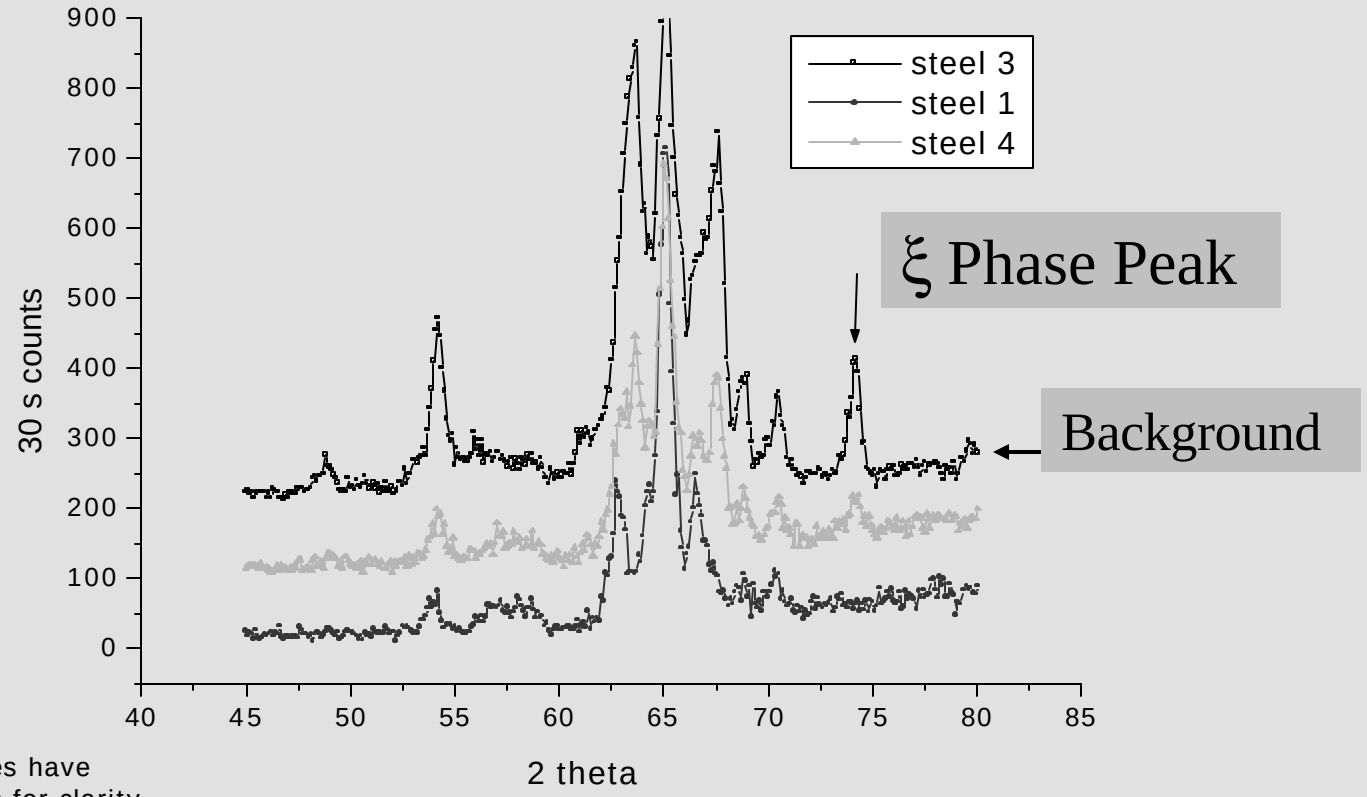
Bragg-Brentano Geometry





Use of parallel-beam approach eliminates problem with sample displacement which previously caused intensity variation and peak shift.

Galvanneal Spectrum



The Black and Green Curves have been shifted by 100 counts for clarity. The Red curve is the baseline

Task Performance

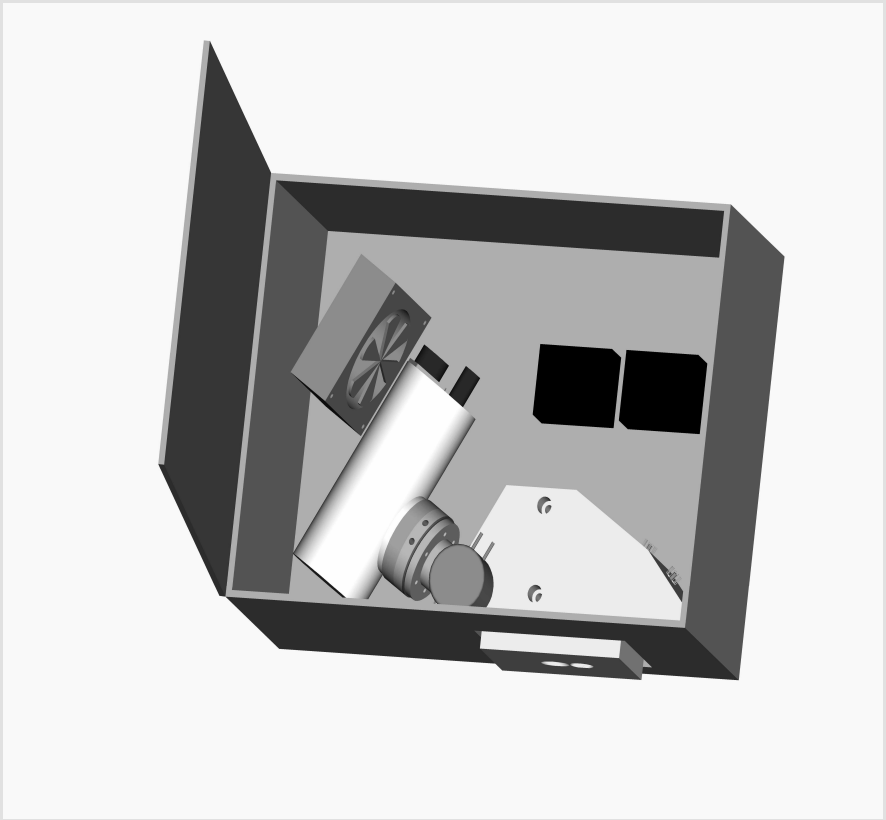
Past Technical Milestones

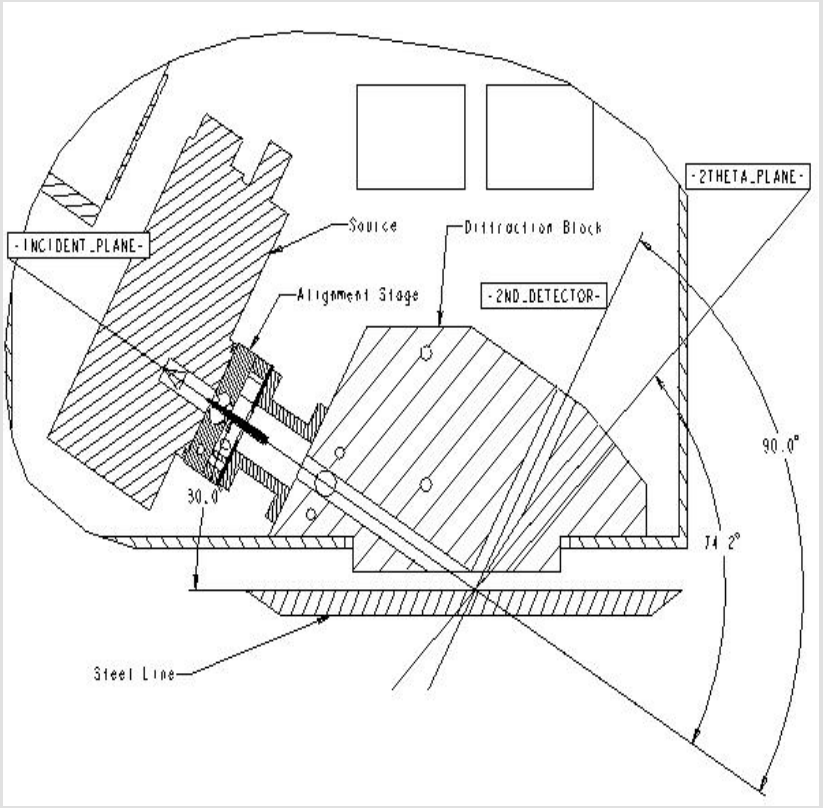
Milestone	Due Date	Completion Date	Comments
Proof of concept	7/00	7/00	Parallel Beam Geometry
Sensor component selection	12/01	12/01	X-ray sources, optics, detectors…
Bench Top Testing	2/02	2/02	

Progress Toward Performance Goals

- **Form Factor**
  - Low power x-ray source
  - Parallel-beam x-ray optic
  - Two-position detection system
  - Housed in NEMA style box on production line
  - Electronics housed in NEMA style box near production line

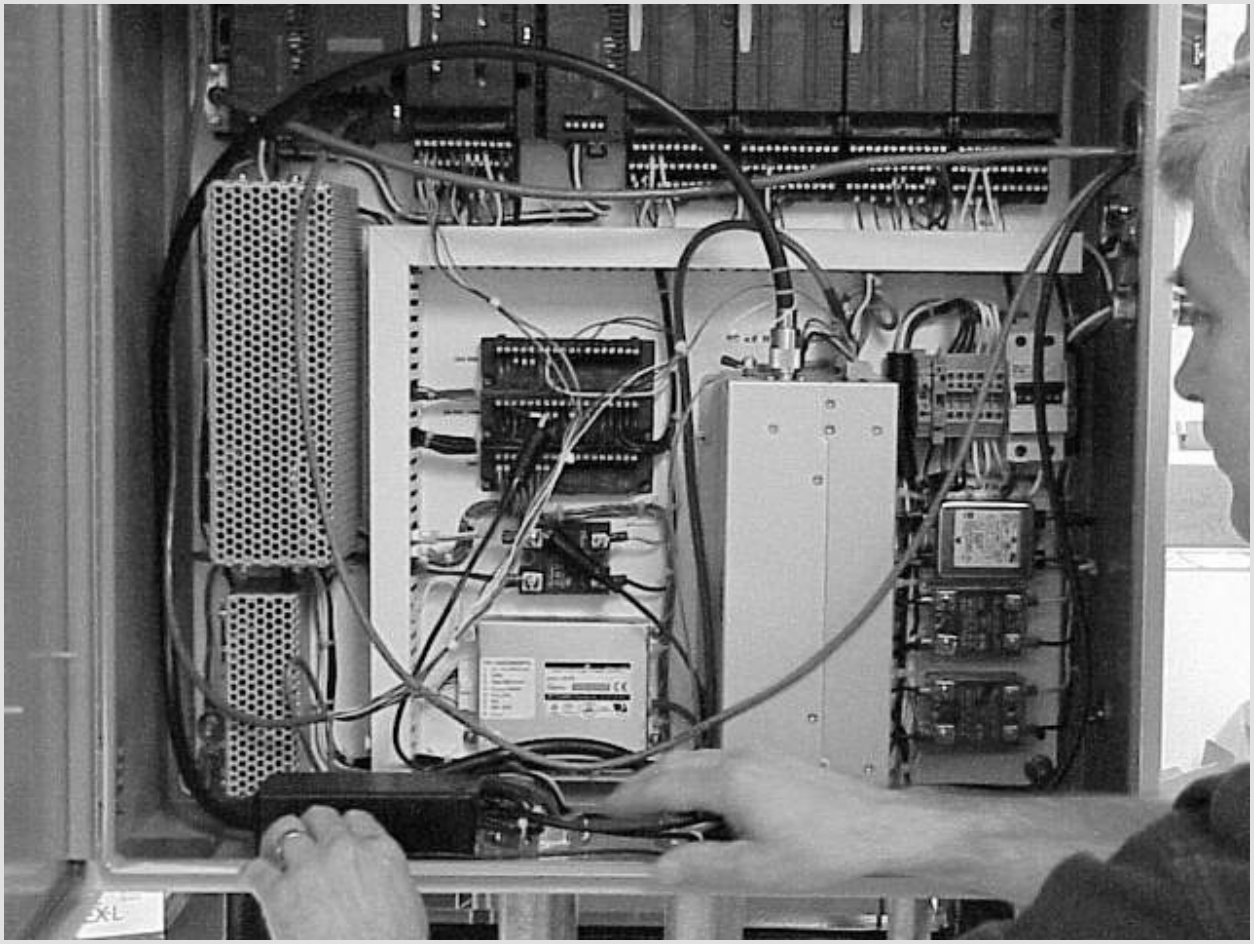
Sensor Engine Cross Section





Compact, no moving parts, sealed from the environment

Galvanneal Sensor Electronics



Galvanneal Sensor Electronics will be installed near the production line

Comparison of two systems

- System miniaturization and simplification
- Greatly expand the applicability of x-ray analytical techniques.

X-ray sources without optics

Need for higher intensity → Higher power

↓

Size of washing machine

X-ray sources with integrated optics

Need for higher intensity → Low power + optics

↓

Size of shoebox

Path Forward

Future Technical Milestones

Milestone	Due Date	Comments
Assemble Sensor	7/31	
Bench test sensor at XOS facility	8/15	Verify performance
Install sensor at AK Steel	9/1-9/30	On slitting line
Collect data at AK Steel	10/15	
Final Phase II Report	12/30	

Performance Merits

The XRD System will improve productivity of the galvannealing process:

- Reduction of out-of-spec product:
  - Reduction of yield loss (1%)
  - Savings of 50,000 N.T. (U.S)

- Minimization of fine-tuning period when switching from product to product or galvanizing to galvannealing:
  - Cut fine-tuning time in half
  - Savings of 42,000 N.T. (U.S.)

Performance Merits

The XRD System will improve product quality by allowing continual monitoring of zeta phase:

- Control that product meets spec.
- Documentation: Is the galvannealed steel really causing the problem at the automaker?

  => Improved stamping processes at the automakers.
- Sub-standard product will not be used in cars.

Performance Merits

The XRD system will reduce costs by reducing:

- Energy costs associated with out-of-spec product.
- Lost revenue from out-of-spec product, due to:
  - Process variation.
  - Fine-tuning during changeover.

Cost Savings ($ millions)

	Quality	Fine-Tuning	Energy	Total
USA	**$24**	**$17**	**$1**	**$ 42**
World	**$86**	**$61**	**$4**	**$151**

Performance Merits

- **The XRD System will reduce the energy that is wasted by the production of out-of-spec product:**
  - Galvannealing is the second-most energy-intensive process in steelmaking, second only to ironmaking.
  - Out-of-spec product is sold for applications which would not require the high-energy input.

U.S. and World Energy Savings

	Production (000 N.T.)	**Yield Savings (000 N.T.)**	**Energy Savings ($000)**
USA	**5,000**	**50**	**$1,030**
World	**18,000**	**180**	**$3,709**

Other Applications for Online XRD

Steel:

Online XRD could provide important monitoring and control for many important process parameters/ specifications in the steel manufacturing process:

- Mechanical properties of semi-finished and finished steel products. (phase, texture, and stress)
- Coating quality of galvannealed, galvanized, and electrogalvanized product. (phase)
- Surface contamination, oxides, and corrosion. (phase)
- Mineral analysis of raw scraps. (phase)

Other Applications for Online XRD

Other Industries:

Online XRD could provide important monitoring and control for many important process parameters/ specifications in other industries:

Aluminum
- Alloy phase
- Texture
- Stress

Cement
- Component phase
- Free-lime content
- Particle size

Pharmaceutical- active ingredient
- Quantity
- Correct polymorph

Semiconductor- thin film
- Stress
- Texture
- Crystal orientation

Questions?